CLINICAL STUDIES

Coronary Artery Surgery in Women Compared With Men: Analyses of Risks and Long-Term Results

FLOYD D. LOOP, MD, FACC,* LEONARD R. GOLDING, MD, FACC,*
JULIE P. MACMILLAN, MPH,† DELOS M. COSGROVE, MD, FACC,*
BRUCE W. LYTLE, MD, FACC,* WILLIAM C. SHELDON, MD, FACC‡

Cleveland, Ohio

A surgical experience with 2,445 consecutive women who underwent isolated bypass grafting was analyzed for comparison with 18,079 consecutive men. Severe or unstable angina occurred preoperatively in 60% of women and 45% of men ($p<0.0001$). Despite less three vessel disease (44 versus 56%, $p<0.001$) and better left ventricular contraction (normal in 60% of women and 53% of men [$p<0.001$]), women had a higher operative mortality rate (2.9 versus 1.3%). When matched for age, severity of angina and extent of coronary atherosclerosis, women still had twice the operative mortality of men. In matched patients, body surface area was the strongest predictor of operative risk, even when the model was adjusted for gender. When the model was adjusted for body surface area, gender was not an important predictor of operative death. The smaller size of women, rather than their sex, appears to explain the difference in operative mortality.

After a mean interval of 2 years, women had a lower overall graft patency rate (76.4%) than men (82.1%) ($p<0.001$). At 5 and 10 years postoperatively, a higher percent of men were angina-free. Yet, survival for women (90.6%) and for men (93.0%) at 5 years, and at 10 years (78.6 and 78.2%, respectively) was not dissimilar.

Most of our knowledge about coronary artery surgery has been compiled from operative experience in men. During the past 15 years, we have witnessed a greater reduction in coronary bypass operative mortality in men than in women. Recently, in a large multi-institutional study (1,2), numerous clinical and angiographic variables were evaluated by univariate analysis for their effect on operative mortality. Six variables that contained the most predictive information were subjected to discriminant analysis. After age and left main coronary artery obstruction of more than 90%, female sex was the third most important operative risk factor in coronary artery surgery. Gender was a stronger indicator of operative risk than was left ventricular impairment.

Because no comprehensive analysis of risks, clinical benefit and longevity in women compared with men exists, we reviewed our entire experience in isolated bypass grafting from 1967 through 1980. The large sample size makes these data useful in providing information about operative risk and outcome.

From the Department of Thoracic and Cardiovascular Surgery,* Department of Biostatistics† and Department of Cardiology,‡ the Cleveland Clinic Foundation, Cleveland, Ohio. Manuscript received August 17, 1982; revised manuscript received October 12, 1982, accepted October 13, 1982.

Address for reprints: Floyd D. Loop, MD, Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, Ohio 44106.

Clinical Material

Selection of patients. Of the 20,524 patients who underwent isolated coronary bypass surgery between May 1967 and January 1981, 2,445 (12%) were women. By definition, these cases excluded bypass surgery combined with ventricular aneurysmectomy, valve repair or replacement and simultaneous carotid endarterectomy. Otherwise, the series of men and women is consecutive and includes all elective, emergency and reoperative cases.

Patient characteristics. Women ranged in age from 15 to 79 years. The median age for women increased from 44 years in 1967 to 60 years in 1980. Median age overall was 57 years for women and 54 years for men. Premenopausal women predominated until 1971, when the prevalence of older patients began increasing yearly and by the period 1975 through 1980, premenopausal women constituted only 10 to 13% of women patients. Pertinent clinical characteristics and risk factors are compared in Table 1.

Angiographic findings. Severe coronary atherosclerosis was defined as an estimated reduction in luminal diameter of 50% or more. The prevalence of single vessel narrowing of 50% or more in women decreased gradually from 39% in 1967 to 1970 to 18% in 1980. In men, one vessel disease occurred in 56% in 1967 to 1970 and decreased to 9% in 1980 (Table 2). In comparison with men, women had significantly more one vessel ($p<0.0001$) and two vessel ($p=0.0002$) disease and significantly less three vessel disease ($p<0.0001$), and women had less extensive coronary artery disease in all categories of age. Of 585 women aged 50 years or

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Table 1. Clinical Characteristics in Female and Male Surgical Patients 1967–1980

	Women	p Value	Men
Angina		<0.001	
No pain	6.5% (159)		13.3% (2407)
Atypical	9.9% (241)		7.3% (1312)
Mild-moderate*	24.0% (587)		34.6% (6248)
Severe-unstable†	59.6% (1458)		44.8% (8112)
Diabetes§	10.1% (247)	<0.001	6.6% (1199)
Hypertension‖	14.6% (357)		13 7% (2469)
Obesity	19.2% (471)	<0.001	16 2% (2933)
Cigarette smoking**	53.7% (1258)		52.6% (8985)
Previous myocardial infarction documented by electrocardiogram	18.3% (448)	<0.001	29.2% (5288)
Serum cholesterol >250 mg/dl††	58% (1404)	<0.001	43% (7732)
Serum triglycerides >140 mg/dl††	67% (1222)	<0 001	71% (10,121)

* Comparable with New York Heart Association (NYHA) class II or III † NYHA class IV § Requiring insulin ‖Systolic pressure >140 mm Hg and diastolic >90 mm Hg *on admission* ** Queries on smoking were recorded in 2,341 (95 8%) women and 17,082 (94 5%) men †† Cholesterol determined in 99% and triglycerides in 79% of women and men.

younger, 181 (31%) had three vessel narrowing; at 51 to 60 years, the prevalence of three vessel narrowing increased to 466 (43%); at 61 to 70 years, three vessel disease occurred in 358 (58%) and of the 103 women above age 70, 68 (66%) had severe three vessel disease. Left main coronary narrowing of 50% or more in women occurred with approximately the same frequency in these four age categories, varying between 9 and 14%, with an overall prevalence of 11%. Men also showed an increased prevalence of three vessel disease with increasing age: 50 years or less, 2,956 (49%); 51 to 60 years, 4,625 (57%); 61 to 70 years, 2,390 (65%) and more than 70 years, 225 (72%). In contrast to women, left main coronary artery narrowing of 50% or more in men increased from 8% in those younger than 50 years to 23% in those 70 years or older.

Left ventricular contraction was classified as normal in 1,460 (59.7%) women and 9,516 (52.6%) men; mild impairment (one of six left ventricular segments impaired) in 626 (25.6%) women and 5,514 (30.4%) men; moderate impairment (two or three segments impaired) in 264 (10.7%) women and 2,270 (12.5%) men and severe impairment (four to six segments impaired) in 95 (3.8%) women and 779 (4.3%) men. Ejection fractions were determined inconsistently. Significant differences between men and women in all four categories of ventricular contraction were found ($p<0.001$). Women showed consistently better preoperative left ventricular performance each year in comparison with men.

Prevalence of operations on women. Of the first 740 coronary artery operations (1967 to 1970), 109 (14.7%) were performed on women. In 1971, operations on women constituted 10.0% of the isolated bypass procedures. The number of women undergoing surgery and their annual percentage of total cases have increased each year from 1971 to 1980. In 1980, women accounted for 13.2% of cases. In all years, a total of 11.9% of operations were performed on women.

Results

Operative mortality. Operative mortality is defined as death in the operating room or thereafter during the same hospitalization. After the early experience (1967 to 1970) in which the operative mortality rate for women was 7.3% (8 of 109), the mortality rate in the next 10 years, through 1980, ranged from 0.8 to 4.5%. Overall operative mortality was 71 of 2,445 (2.9%) for women and 242 of 18,079 (1.3%) for men ($p<0.001$). Mortality was significantly higher in women aged 60 years or less in comparison with men (Table 3). Above age 60, mortality in men increased and although mortality remained higher in women, it no longer was statistically significant. Table 4 shows operative mortality based on extent of coronary atherosclerosis. Operative mortality correlated with number of bypass grafts showed no significant difference between women and men for one or two grafts. For three grafts, mortality was 24 of 575 (4.2%) in women and 89 of 5099 (1.7%) in men ($p<0.001$). Of those who received four or more grafts, 9 of 121 (7.4%) women and 21 of 1,842 (1.1%) men died ($p<0.001$).

In categories of normal left ventricular performance and mild and moderate impairment, women showed a significantly higher operative mortality rate: normal performance, women 2.5% (36 of 1,460) versus men 1.1% (103 of 9,516) ($p<0.0001$); mild impairment 2.9% (18 of 626) and 1.3% (72 of 5,514) ($p=0.002$); moderate impairment, 5.7% (15 of 264) and 2.0% (46 of 2,270) ($p<0.001$). In severe left ventricular dysfunction, an operative mortality rate for women of 2.1% (2 of 95) was similar to that for men (2.7%; 21 of 779).

Table 2. Coronary Atherosclerosis (≥50% estimated reduction in luminal diameter) of Major Coronary Arteries

	Women	p Value	Men
One vessel	22% (541)	<0 0001	13% (2,404)
Two vessel	34% (831)	=0.0002	30% (5,479)
Three vessel	44% (1,073)	<0 0001	56% (10,196)
Left main*	11% (272)		11% (2,075)

*Left main coronary atherosclerosis calculated independently

Table 3. Operative Mortality by Age

Age (yr)	Women	p Value	Men
≤50	14/585 (2.4%)	<0.001	37/5997 (0.6%)
51–60	25/1087 (2 3%)	0.013	109/8116 (1.3%)
61–70	24/670 (3 6%)		83/3653 (2.3%)
>70	8/103 (7 8%)		13/313 (4.1%)

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Table 4. Operative Mortality Correlated With Preoperative Extent of Coronary Atherosclerosis

	Women	p Value	Men
One vessel	1.1% (6/541)		0.7% (16/2404)
Two vessel	2.3% (19/831)	=0.008	1.2% (64/5479)
Three vessel	4.3% (46/1073)	<0.001	1.6% (162/9971)
Left main	7.0% (19/272)	<0.001	2.9% (61/2075)

Table 5. Stepwise Logistic Regression Analysis of Operative Risk for 2,445 Women

Step Number	Variable	Improvement χ^2	DF	p Value
1	Number of vessels≥50%	24.355	3	<0.001
2	Emergency operation	6.611	1	0.010
3	Number of grafts	7.188	3	0.066
4	Angina severity	6.700	3	0.082

Completeness of revascularization. For the purpose of this study, completeness of revascularization is defined as grafts anastomosed to all major coronary arteries that have an estimated 50% or greater reduction in luminal diameter documented by coronary cineangiography. Nondominant right coronary arteries were not considered in the completeness evaluation. Sixty-six percent of women (1,614 of 2,445) had complete revascularization in comparison with 60% of men (10,831 of 18,079) ($p<0.001$).

Complications. Perioperative myocardial infarction is defined as the appearance of new Q waves; in almost all patients, there was a concordant elevation in serum cardiac enzymes. According to these criteria, 90 women (3.7%) and 526 men (2.9%) experienced infarction ($p=0.036$). In women, the rate of perioperative myocardial infarction ranged from 14 to 18% in 1967 to 1969, stabilized at 4.6 to 5.9% from 1972 to 1976 and decreased to 1.8 to 2.8% from 1977 to 1980. In men, the rate of perioperative infarction averaged 4.1% through 1976 and 1.5% from 1977 to 1980. The rate of atrial fibrillation ranged from 6 to 15% and has averaged 10% for women and 12% for men during the past 5 years. Neurologic deficit occurred in 2.4% of women and 1.5% of men. Reoperation for bleeding was necessary in 3.8% of women and 5.5% of men. Intraaortic balloon pump support was used in 60 women (2.5%), of whom 11 (0.6%) received the device preoperatively, 43 (1.7%) intraoperatively and 6 (0.2%) after the first 24 hours postoperatively. In men, the incidence rate of balloon usage (1.2%) was less than in women with approximately the same distribution.

Operative risk analysis. *Logistic regression analysis.* Risk factors were determined in 2,445 women by stepwise logistic regression analysis. Four variables were significant predictors of operative mortality: number of arteries with 50% or greater obstruction, emergency operation, number of grafts and severity of angina (Table 5). In a similar analysis in men, seven variables were selected: emergency operation, reoperation, ventricular conduction defect, age greater than 70 years, number of arteries with 50% or greater obstruction, electrocardiographically documented myocardial infarction and left ventricular impairment (Table 6).

Matched pairs analysis. Women were matched with men on the basis of age, severity of angina and extent of coronary atherosclerosis. In the matched pairs, there were 69 operative deaths (2.9%) in 2,402 women and 33 operative deaths (1.4%) in 2,402 men.

Body surface area was analyzed in these 2,402 patients to compare relative strengths of gender and body surface area as predictors of operative death. Body surface area in women ranged from 1.10 to 2.22 m^2 (mean 1.66 m^2 ± 0.003 SEM). In men, body surface area ranged from 1.06 to 2.64 m^2 (mean 1.92 m^2 ± 0.003). Two covariates, body surface area and gender, were used in discriminant analyses to determine a binary outcome (operative death or no death). The two covariates, and body surface area and gender, adjusted and not adjusted for each other, are shown in Table 7.

Body surface area was a significant risk predictor whether the model was unadjusted or adjusted for any of the other variables (that is, people of the same gender), but different body sizes had different risks of operative death. Gender was significant whether viewed alone or adjusted for the basic variables (Table 7); however, when one adjusts for body surface area, gender as such is not an important risk factor for operative death. Men and women of the same size having the same status of other variables do not have significantly different risks of operative death. Body surface area then is the most important risk factor for operative

Table 6. Stepwise Logistic Regression Analysis of Operative Risk for 18,079 Men

Step Number	Variable	Improvement χ^2	DF	p Value
1	Emergency operation	115.277	1	<0.001
2	Reoperation	29.639	1	<0.001
3	Ventricular conduction defect	13.797	1	<0.001
4	Age >70 years	51.093	3	<0.001
5	Number of arteries diseased	22.179	3	<0.001
6	Documented previous myocardial infarction	8.479	1	0.004
7	Left ventricular impairment	5.787	3	0.12

death among the variables considered in this study. Smaller people, regardless of gender, are at increased risk of dying during surgery even after considering the other variables.

Graft patency and left ventricular contraction. Recatheterization in 466 women and 4,338 men yielded the graft patency rates shown in Table 8. Of 502 women who had normal ventricular contraction or only mild impairment preoperatively and were later restudied, 464 (92.4%) remained in the same ventricular function category. A subjective estimate of worse left ventricular contraction was reported in 38 of 502 (7.6%) women. Of 53 women with moderate to severe left ventricular impairment preoperatively, 27 (50.9%) showed improvement; the condition of 16 (30.2%) remained the same and 10 (18.9%) showed additional impairment. In men, 3,916 of 4,450 (88.0%) who originally had normal contraction or only mild impairment remained in the same condition and 534 (12.0%) showed further impairment of left ventricular contraction on recatheterization. Of 518 men who had moderate to severe left ventricular impairment preoperatively, 258 (49.8%) had subjective evidence of left ventricular improvement; 186 (35.9%) remained in the same condition and the contraction worsened in 74 (14.3%). Thus, at an average of 2 years postoperatively, recatheterized women had about the same preservation of left ventricular contraction as men. Among patients with normal contraction or only mild impairment preoperatively, women had less evidence of new impairment than men (7.6 versus 12.0%, $p=0.003$).

Symptom relief. Symptom relief was determined at 10 years for survivors of the 1967 to 1970 cohort of 740 consecutive patients and for the first 1,000 patients operated on in 1971 and 1972. For the 1967 to 1970 cohort, 42 (57.5%) of 73 surviving women and 320 (63.4%) of 505 surviving men were asymptomatic at 10 years (not significant). For the 1971 and 1972 cohorts, 84 (56.0%) of 150 surviving women were angina-free in comparison with 944 (65.8%) of 1,435 surviving men at 10 years ($p=0.017$). All survivors among the first 1,000 surgical patients each year from 1973 through 1977 were contacted for a minimal follow-up time of 5 years. At 5 years, 298 (60.5%) of 492 women were angina-free in comparison with 2,938 (71.5%) of 4,112 men ($p<0.001$).

Five and 10 year survival. Cumulative 5 year survival was determined for the first 1,000 patients coming to operation each year from 1973 to 1977. All early and late deaths were included regardless of cause. Actuarial survival at 5 years for women was 90.6% and for men, 93.0% ($p=0.035$) (Fig. 1). When operative mortality is excluded, there is no significant difference in 5 year survival. In the 1967 to 1970 group of 740 patients, 109 women were operated on, but the series was skewed by predominance of one vessel disease (56%). Therefore, the first 1,000 patients in 1971 and 1972 were used for 10 year survival comparison in women and men (Fig. 2) that was 78.6 and 78.2%, respectively (not significant).

Discussion

Clinical characteristics. Women with suspected coronary artery disease show distinct differences from men. Women with chest pain, even those with typical angina, are more likely to have angiographically normal coronary ar-

Table 7. Relative Predictive Information in Gender, Body Surface Area and Two Covariates

Variables	Adjusted for	Predictive Information	F Statistic	p Value
Emergency operation and left ventricular impairment (basic variables)		0.42	4 98	0.0001
Basic + gender		0.55	10 92	0.0001
Basic + body surface area		0 66	13.11	0.0001
Gender + body surface area		0.24	11.93	0.0001
Basic + gender + body surface area		0.66	10 94	0.0001
Body surface area		0.24	23.75	0.0001
Body surface area	Gender	0.11	10 85	0.001
Body surface area	Basic	0.24	23.08	0.0001
Body surface area	Gender + basic	0 11	10.62	0.001
Gender		0 13	13 01	0.0001
Gender	Body surface area	<0.01	0 13	0.72
Gender	Basic	0.13	12 62	0.0004
Gender	Body surface area + basic	<0.01	0 11	0.74

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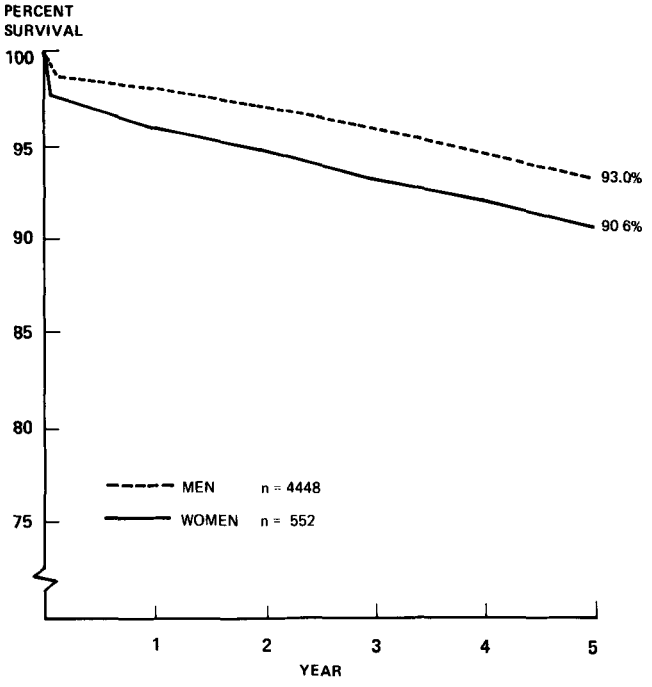
Table 8. Vein and Internal Mammary Artery Graft Patency Rates

	Women	p Value	Men
Vein graft*			
Right coronary	68.5% (183/267)	0.007	76.0% (1855/2440)
Circumflex	69.8% (118/169)	0.017	77.8% (1768/2273)
Anterior descending	79.4% (193/243)		83.7% (1963/2344)
Diagonal	73.1% (38/52)		80.5% (412/512)
Totals	72.8% (532/731)	<0.001	79 2% (5998/7569)
Internal mammary artery†	92.6% (151/163)		95.4% (1578/1654)

*Mean recatheterization interval for women 23 months and men 24 months.
†Internal mammary artery grafts had been constructed to the anterior descending in 95% of those restudied.
Figures in parentheses indicate number of grafts.

teries than are men with comparable symptoms (3). In one report, 37% of the women referred for coronary arteriography because of presumed angina pectoris had normal coronary arteries (4). In the Coronary Artery Surgery Study (CASS), 40% of women undergoing cardiac catheterization for suspected coronary atherosclerosis had normal coronary arteries and another 10% had mild arterial narrowing (5). These figures contrast sharply with those for men: 12% had normal coronary arteries and 5% had mild coronary narrowing. In a study of 1,000 women under 50 years of age with suspected coronary atherosclerosis, only 128 (58%) of 222 with typical angina had 50% or greater obstruction

Figure 1. The first 1,000 patients operated on each year from 1973 through 1977 were followed up for a minimum of 5 years. All early and late deaths and deaths from all causes were included. Five year actuarial survival for women (90.6%) was significantly less than that for men (93.0%) ($p = 0.035$) if operative deaths are included.



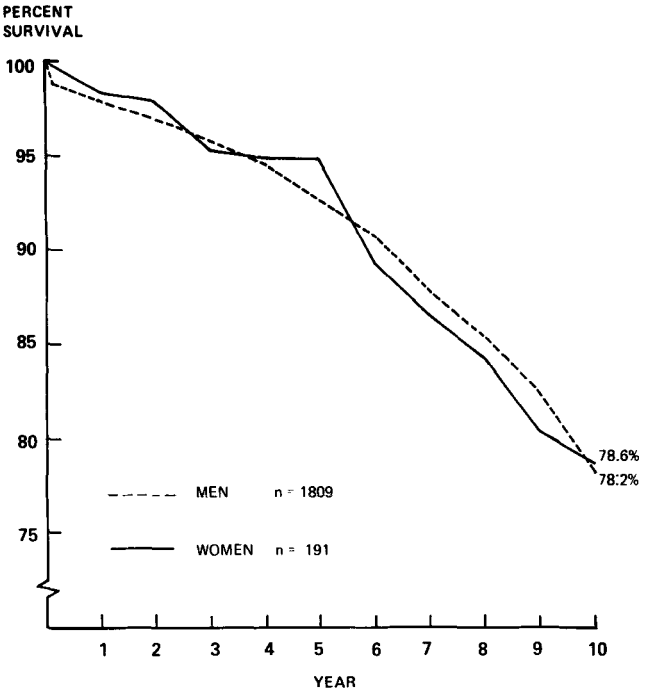


Figure 2. The first 1,000 patients operated on each year in 1971 and 1972 were followed up for a minimum of 10 years. As in the 5 year survival determinations, all early and late deaths from all causes were included. Ten year survival for women was 78.6% in comparison with 78.2% for men.

visualized angiographically in one or more coronary arteries (6). It appeared difficult to make a clinical diagnosis that correlated well with arteriographic findings in young women; these data imply that the strategy for distinguishing severe coronary atherosclerosis in women with chest pain by clinical or noninvasive methods is highly ineffective.

The natural history of proved, severe coronary arteriosclerosis in women and men was the subject of a 15 year study by Proudfit et al. (personal communication). Forty women and 346 men who underwent coronary arteriography from 1964 to 1966 were selected as potential surgical candidates because of focal narrowing, good arterial runoff and well preserved left ventricular function. After medical treatment alone, survival in women at 5, 10 and 15 years was 78, 54 and 40%, respectively. Survival in men at 5, 10 and 15 years was 69, 49 and 37%. All deaths from all causes were included. Differences in survival between women and men were insignificant.

In our present review of 2,445 women who underwent coronary artery surgery, we found more severe angina preoperatively in women than in men. Angina was frequently more unstable in women. This finding contrasted with evidence that surgically treated women had less extensive coronary atherosclerosis and overall better left ventricular performance than men. In surgically treated CASS patients, left main or three vessel coronary disease occurred less frequently in women than in men for chest pain categories

of definite angina, probable angina and nonspecific chest pain (7). Multivessel disease was infrequent in women with nonspecific chest pain. We confirm their findings that the prevalence of detected three vessel disease increases sharply with each decade of life in women just as it does in men, but the prevalence of left main stenosis increases with advancing age more in men than in women.

Operative mortality. Reports of early results have shown, with few exceptions, that operative mortality is higher in women despite the improvement in mortality and morbidity observed in the latter half of the 1970s (Table 9). Women had approximately twice the operative mortality of men. In our series, women younger than 60 years had a significantly higher operative mortality than did men in the same age category. After 60 years of age, mortality increased in men and the differences became insignificant. These findings parallel the CASS experience (2). Emory University investigators (14) reported a similar higher operative mortality in women; however, when they matched women to men by age, severity of angina and extent of coronary atherosclerosis, the matching process equalized operative mortality at 2%. When we matched women to men based on those three clinical variables, our operative mortality remained twice as high in women as in men (2.9 versus 1.4%).

Coronary artery spasm is an unlikely explanation for the greater operative mortality in women. Spontaneous or ergonovine-induced coronary artery spasm occurs with nearly equal frequency among women and men (15). Although perioperative spasm in ungrafted arteries has been implicated in the deaths of two patients recently, overall operative mortality in the series described herein was largely attributed to ischemia-infarction related to poor myocardial protection. Instability preoperatively may contribute to irreversible myocardial damage, but coronary artery spasm as such does not appear to be an important cause of early death.

The CASS investigators (16) concluded that the increased risk involved in coronary artery surgery in women was accounted for by small stature and by small diameter of coronary arteries. In their study, operative mortality for women and men decreased as height and vessel diameter increased. In other words, the smaller patient, woman or man, faces heightened risk of operative mortality after allowing for differences in other risk factors. We believe that coronary artery diameter as measured with calibrated probes by numerous surgeons is inaccurate and that vessel diameter of itself does not take into context the effect of diffuse atherosclerosis, graft stenosis or early graft closure.

Vein graft patency. After a mean interval of 2 years, the rate of vein graft patency was significantly lower in women (72.8%) than in men (79.2%) ($p<0.001$). In the early years of bypass surgery, routine cardiac catheterization was performed frequently at 1 year postoperatively. After the first few years, only patients with recurring symptoms had recatheterization so that, overall, 65% of both women and men were restudied because of recurring angina. Postmortem studies indicated smaller vessel size in women, which may explain the discrepancy in graft patency rates (17). A myth exists that the internal mammary artery is too small for myocardial revascularization in women. Note that the internal mammary artery graft patency was nearly equal (92.6 versus 95.4%) (not significant) in women and men.

Follow-up. Relief of angina 5 and 10 years postoperatively was less in women than in men; this was statistically significant at both 5 and 10 years. In the Emory University matched group (14), 53% of women with complete revascularization were asymptomatic after a mean follow-up period of 42 months compared with 71% of men.

Five and 10 year longevity for women and men were nearly the same. The 5 year survival rate for women was 90.6% and for men, 93.0%; at 10 years the rates were 78.6 and 78.2%, respectively. The Emory University experience (14) recorded a 92% survival at 42 months for both women and men. Greene et al. (18) found that 5 year survival after isolated myocardial revascularization was indistinguishable from that of the United States population matched for age and sex. However, when the female surgical subset was compared with the 1975 U.S. population, 5 year survival was 92.6 versus 96.1%, which came closest of all subsets to lying outside the 95% confidence interval. Killen et al. (13) found that in contrast to men, women did not achieve

Table 9. Reported Operative Mortality in Isolated Coronary Artery Surgery

First Author	Series Years	Women*	Men*
Sheldon (8)	1967–1970	7.3% (109)	2.2% (631)
Bolooki (9)	1969–1973	8.8% (34)	2.0% (51)
Wukasch (10)	1968–1977	6.6% (1,218)	3.0% (7,843)
Tyras (11)	1970–1977	3.7% (241)	2.4% (1,300)
Golding (12)	1971–1975	1.7% (877)	1.2% (7,064)
Killen (13)	1971–1976	1.3% (385)	0.9% (2,243)
Douglas (14)	1973–1979	2.2% (492)	1.0% (2,663)
Kennedy (2)	1975–1978	4.5% (1,061)	1.9% (5,569)
Present series	1967–1980	2.9% (2,245)	1.3% (18,079)

*Figures in parentheses in these two columns indicate number of patients

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the expected 5 year survival pattern of the general population matched for age and sex. These discrepancies may result in part from the fact that American women in the general population have a higher 5 year survival than men matched for identical age.

Clinical implications. Throughout the 14 year experience, women have been at higher operative risk than men. Analysis of clinical risk factors indicates that body surface area (physical size) is the most important predictor of operative risk. When one adjusts the population for similar body surface area, gender in itself is no longer a significant risk factor for operative death. The increased risk related to small stature probably correlates with small cardiac size and diminutive coronary arteries; however, we did not measure coronary luminal diameter. Although women had less extensive coronary atherosclerosis and better left ventricular function preoperatively, severe and unstable angina occurred more frequently. Therefore, ischemia coupled with diminished cardiac size may explain the differences in risk. Despite a higher operative mortality rate, lower graft patency rate and less relief of angina, the 5 and 10 year survival rates for women were comparable with those of men. This study and other published reports serve to document differences in early results and later clinical benefit. It may be prudent to advise female surgical candidates that their risk of operative death is slightly higher and that relief of anginal symptoms may be less than expected after bypass surgery, but that longevity is comparable with that found in men.

APPENDIX

Statistical Methods

Chi-square tests were used to determine significant differences in clinical characteristics, graft patency and symptom response among women and men.

In analyzing operative death frequency, women were matched to men by age (exact year), angina and extent of disease. When more than one man matched a woman, the man having the closest surgical date was used; except for the very early years, this match was usually within a year of the woman's operation. This resulted in 2,402 pairs; only 43 of 2,445 women had no suitable match among the men. These matching variables were considered *a priori* to be related to operative risk.

The body surface area measurements were available for all 2,402 pairs, and these people were used to compare the relative strengths of gender and body surface area as predictors of operative death. This analysis was done with the general methodology discussed by Fisher et al. (16). A stepwise analysis was used first to select covariables from the variables listed in Table 2. These covariables, along with body surface area and gender, were used in the Statistical Analysis System general linear model to analyze a binary outcome (operative death or no operative death) (19). Each effect was assessed both by itself and with the model adjusted for combinations of the other effects.

For single sex analyses, variables predictive of operative death were selected by stepwise logistic regression analyses performed for all men and women. Variables eligible for the model were those univariately associated with operative mortality (at $\alpha = 0.05$ for women and at a smaller $\alpha = 0.01$ for men because of the larger sample size). Table 10 shows these variables and their univariate significances.

Table 10. Significance Levels From Chi-square Test of Each Variable's Association With Operative Death

Variable	p Value		
	Women	Matched Men	All Men
Age category	0.01	0.14	<0.01
Duration of symptoms	0.29	0 44	<0.01
Angina class	0.08	0.31	0.32
Clinical diabetes	0.47	0.42	0.80
Hypertension	0 20	0.22	0.18
Electrocardiographically documented MI	0 35	0.06	<0.01
Clinical history of MI	0.28	0.53	0.35
Smoking	0 46	0.14	0.46
Cholesterol	0.35	>0.99	0.62
Number of grafts	<0.01	0.05	0.01
Revascularization	0 83	0 13	0.01
Ventricular conduction defect	0.15	0.05	<0.01
Emergency operation	<0.01	<0.01	<0.01
Reoperation	0.60	0.86	<0.01
Cardioplegia	0 92	0 07	0 11
No. arteries ≥50% occluded	<0.01	0.21	<0.01
Left ventricular impairment	0.04	0.02	<0.01

MI = myocardial infarction

Long-term survival for men and women was analyzed via the Mantel-Haenszel procedure (20).

Addendum

In the first 1,000 patients entered into our Cardiovascular Information Registry for 1981, operative mortality for women was 3 of 149 (2.0%) in comparison with 1 of 851 (0.1%) for men. In the 1982 cohort, operative mortality was 0 for 161 women and 4 of 839 (0.5%) for men.

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